Areal Extent, Hydrogeologic Characteristics, and Possible Origins of the Carbonate Rock Newburg Zone (Middle–Upper Silurian) in Ohio[1]

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ABSTRACT. The name Newburg has been applied to a highly permeable zone, 0.3 to 9 m thick, occurring in a granular or vuggy dolomite. The zone occurs in carbonate rocks of Middle to Late Silurian age across much of Ohio. Known also to well drillers as the "Second Water" in the "Big Lime" carbonate sequence, the Newburg zone is a source of hydrocarbons in northeast Ohio, brines in southeast Ohio, and a widespread source of water over much of west-central Ohio. Close to recharge areas, the quality of the water is comparable to that of the overlying carbonate rocks; thus, the Newburg zone warrants further investigation as a source of water for domestic use.

Theories for the porosity and permeability of the Newburg zone include: 1) deposition of carbonate or quartz sand along an erosional surface and later lithified to porous and permeable sandstone; 2) dissolution of fossils within Silurian reef complexes; 3) fracture-induced porosity along thrust faults developed during the Alleghenian orogeny; and 4) a combination of these processes.

Differences of the characteristics of the Newburg zone and interpretation of these characteristics at different localities indicate that the multiple-process theory is valid and that the Newburg zone is not a single, continuous stratigraphic feature.

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INTRODUCTION

Increasing needs for ground water have stimulated exploration for sources of potable water within the carbonate bedrock of central Ohio. The Newburg zone is a drillers' term used to describe a highly permeable carbonate rock zone in the Middle to Upper Silurian that yields brine mixed with hydrocarbons in eastern Ohio and is a source of potable water in west-central Ohio. In Franklin County (Fig. 1), notably at Harrisburg and at Plain City, the zone yields up to 5,450 m^3/day to municipal wells. Although the Newburg zone is becoming recognized as an important water source in west-central Ohio, few domestic wells tap the zone because of the depth. For example, it lies 100 to 200 m below land surface in western Franklin County (Norris 1956).

Literature describing the extent of the Newburg zone throughout Ohio is sparse. Floto (1955) described wells in the Mayfield gas field, Cuyahoga County, which produced 340 million m^3 of gas from the Newburg zone in the first 11 years, and oil fields in Fairfield County, with a reported initial production from the Newburg zone of 5 to 140 barrels per day. In describing water-supply potential, Norris (1956) concluded that, "Yields from the Newburg far exceed yields commonly obtained from wells drilled generally into the limestone deposits. Supplies at least in the magnitude of 0.5 to 1 million gallons per day (1,900 to 3,800 m^3/day) probably are available from the Newburg at many places in west-central Ohio."

Interest in the Newburg zone has been stimulated recently by the start of the Ohio-Indiana Carbonate Bedrock and Glacial Regional Aquifer-System Analysis (RASA), one of several regional aquifer studies being done by the U.S. Geological Survey throughout the United

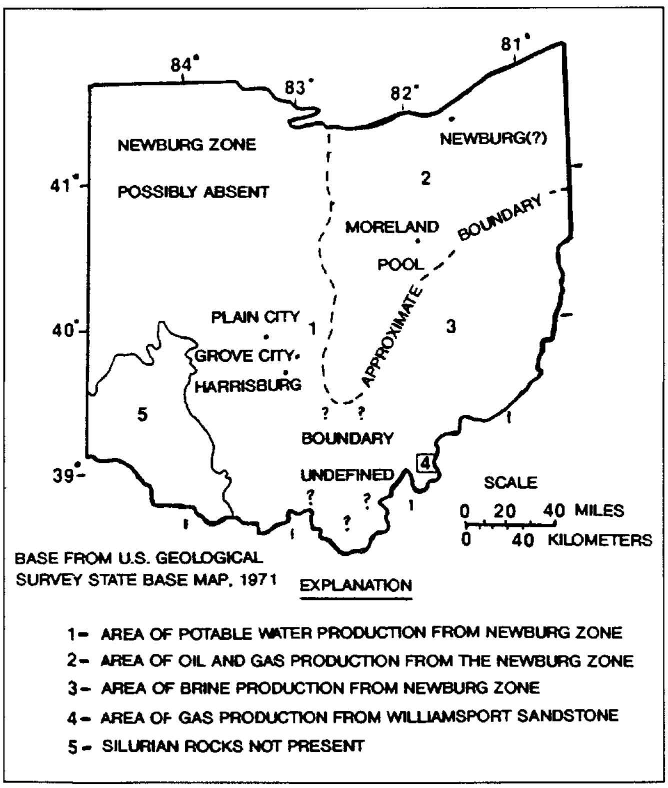

FIGURE 1. Approximate distribution of hydrocarbons, brine, and water produced from the Newburg zone in Ohio. (Compiled from Norris 1956, Multer 1963, Norris and Fidler 1971, Janssens 1975.)

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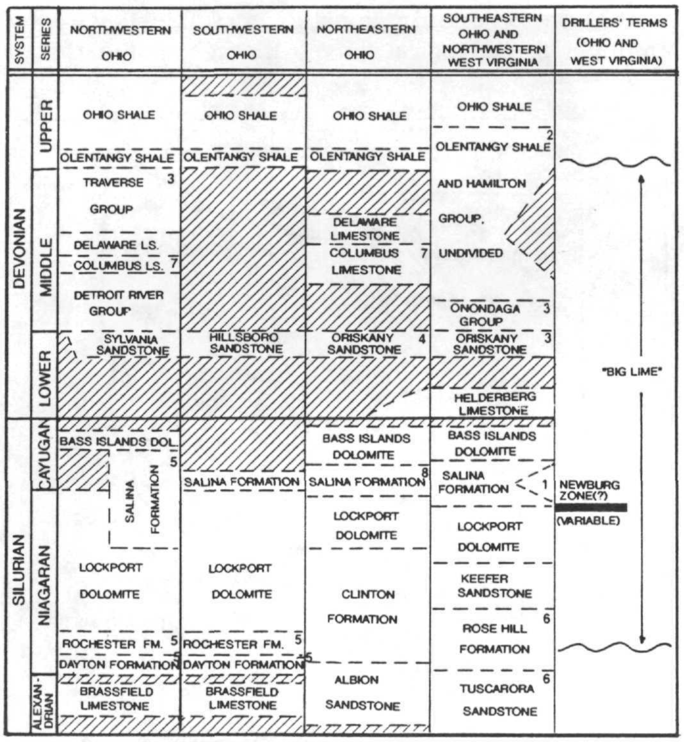
States (Sun 1984). A major purpose of the RASA is to determine the hydrogeologic characteristics of the carbonate aquifer system in the Silurian and Devonian rocks in eastern Indiana and western Ohio. The Newburg zone may thus play a significant regional role in the RASA carbonate-bedrock aquifer study. The purpose of writing this paper is to describe the areal extent and hydrogeologic characteristics of the Newburg zone compiled from available data and to present the various theories of the sedimentological or tectonic origin that have been proposed for this zone.

AREAL EXTENT AND GEOLOGIC CHARACTERISTICS OF THE NEWBURG ZONE

Definition

The "Newburg zone" is a drillers' term originally applied to an oil- and gas-yielding rock sequence or unit near the contact between the Lockport Dolomite of Middle Silurian age and the Salina Formation of Late Silurian age in eastern Ohio (Fig. 2). The name is derived from the village of Newburg (renamed or no longer in existence), southeast of Cleveland, OH, where in 1886 gas was produced from a well at a depth between 700 and 800 m (500 to 600 m below sea level) (Orton 1888).

Permeable zones at or near the top of the Lockport Dolomite have been subsequently referred to by many as the Newburg zone at multiple locations throughout Ohio.



1.- NEWBURG SAND AND WILLIAMSPORT SANDSTONE OF WEST VIRGINIA
2.- USGS USAGE-UPPER DEVONIAN ONLY
3.- FOLLOWS USAGE OF THE OHIO GEOLOGICAL SURVEY (SHEARROW 1957)
4.- FOLLOWS USAGE OF THE OHIO GEOLOGICAL SURVEY (DOW 1962)
5.- FOLLOWS USAGE OF THE OHIO GEOLOGICAL SURVEY (JANSSENS 1977)
6.- USAGE IN WEST VIRGINIA ONLY
7.- FOLLOWS USAGE OF THE OHIO GEOLOGICAL SURVEY (OWENS 1970)
8.- FOLLOWS USAGE OF THE OHIO GEOLOGICAL SURVEY (MULTER 1963)

FIGURE 2. Generalized stratigraphic chart for selected areas of Ohio and West Virginia. (Compiled from Shearrow 1957, Janssens 1977, Lindberg 1985, Bugliosi 1990.)
FM. = Formation, LS. = Limestone, DOL. = Dolomite.

Although a consistent stratigraphic position for the Newburg zone may not exist across Ohio, it has been designated by drillers as being present within the "Big Lime." "Big Lime" is a drillers' term referring to the carbonate sequence extending from the Middle Silurian through the Middle Devonian (Owens 1970). Because of the large quantities of water typically yielded by the Newburg zone, drillers commonly have referred to this zone as the "Big Water" within the "Big Lime," and less commonly referred to it as the "Second Water" (Stout et al. 1935). Multer (1963) warned that caution should be observed in the application of a stratigraphic position to the Newburg. Citing communication with G. G. Shearrow (Ohio Geological Survey), Multer wrote that the term "Newburg" has been used for any subsurface, porous, dolomitic zone either in the upper part of the Niagaran Series (Lockport Dolomite) or in the basal Salina Formation. He notes explicitly that this very permeable zone does not have to be specifically at the contact of these two series.

Northeastern Ohio

The Newburg zone of northeastern Ohio is present typically near the top of the Lockport Dolomite near the contact with the overlying Salina Formation of Silurian age (Stout et al. 1932). Janssens (1975) noted that the porous and permeable portions of the Newburg zone are present in the Lockport Dolomite (Middle Silurian) but in places are found in the lower part of the overlying Salina Formation (Late Silurian).

Stout et al. (1932) described this permeable section as a zone of impure, porous dolomite, varying from light gray to pink and ranging in thickness from 0.3 to 9 m. Although they referred to it as the Newburg Formation, this name never became formal stratigraphic nomenclature of the U.S. Geological Survey. They also noted that the Newburg zone locally bears thin lenses of sandstone, which they interpreted to represent ancient shoreline deposits. Cushing et al. (1931) described the "Newburg (or Stadler) sand" (Newburg zone) as a calcareous or dolomitic limestone, more or less pure, and distinctive from the quartzose sand of the Clinton Formation, which is present at greater depth. They described the thickness of the Newburg zone as ranging from 1 to 5 m. Rogers (1917) described the "Newburg sand" penetrated by wells in the Cleveland area as a chocolate-brown, porous phase of the Lockport Dolomite. Multer (1963) described the so-called "Newburg sand" within the Moreland oil pool in Wayne County, OH, as a variably colored and textured dolomite containing numerous sedimentary structures and vugs. He wrote that brown-colored phases and gray-colored phases of dolomite with gradational boundaries occur within the Newburg at this location. Increased porosity and permeability of this zone at the Moreland pool as compared with the surrounding bedrock is attributed by Multer (1963) to vugs created by the solution of fossils.

The composition of the sand in the Newburg zone is another point of discrepancy in the literature. Lafferty (1949) noted that fluids in the Newburg zone can be produced from either crystalline, sugary dolomite or quartz sand. In contrast, Multer (1963), citing a personal communication with G. G. Shearrow (Ohio Geological Survey), stated that the

Newburg zone in Ohio is present only in a porous, sugary dolomite and does not contain beds of quartz sand, although some secondary quartz may line the dolomite vugs. In Multer's (1963) description of the "Newburg sand," he did not observe any evidence of beds of quartz sandstone in the Newburg zone at the Moreland pool.

Bownocker (1910) wrote that wells drilled in Richland County penetrate the oil- and gas-bearing "sand" usually about 195 m below the top of the "Big Lime." However, depths of the "sand" ranging from 119 to 152 m below the top of the Big Lime have been reported for the county.

Southeastern Ohio

Janssens (1975) included the Williamsport Sandstone in his description of the Newburg zone. The Williamsport Sandstone is a quartz sandstone occurring mainly in West Virginia but extending into Meigs County, OH. Janssens referenced drillers' logs in applying the term "Newburg" to this high-porosity zone in West Virginia, but stratigraphic or lithologic correlation to the Newburg zone of central and northeastern Ohio has not been determined. Patchen (1967) explained that the use of the term "Newburg sand" is common in West Virginia drilling terminology to denote the Williamsport Sandstone, hence the use of "Newburg" for this unit in southeastern Ohio. Janssens (1975) analyzed the Newburg zone on a regional scale and defined the zone on the basis of yield, not on stratigraphic occurrence. Collins and Smith (1977), however, wrote that minor amounts of sand deposits have been found at the top of the Lockport Dolomite in Washington County, OH. Woodward (1959) identified this as the Williamsport Sandstone, corresponding with the Group C unit of the Salina Formation of Ohio (Janssens 1975).

Western Ohio

In western Ohio, Norris and Fidler (1973) place the Newburg zone in the lower part of the Bass Islands Group (Late Silurian). They stated that wells penetrating this permeable stratum in west-central and western Ohio provide evidence that the Newburg zone occurs at a specific position in the stratigraphic column. Although evidence for the existence of the Newburg zone in northwestern Ohio was not established by Norris and Fidler (1971), field data strongly indicate that a highly permeable zone is present in western Ohio and is correlative and probably continuous with the Newburg zone of eastern Ohio (Norris and Fidler 1973).

WATER QUALITY IN THE NEWBURG ZONE

The water quality in the Newburg changes from potable to brine along a traverse line from west to east across Ohio. Recharge to the Silurian-age bedrock aquifers occurs in the western part of the state where these units outcrop or subcrop. Although some local discharge occurs in areas where the overlying shale confining units are thin or missing, the majority of the ground water flows down-gradient to the east. The major change in water quality occurs along this flowpath.

In western Ohio, the quality of water in the Newburg zone is comparable to that of water in the overlying carbonate rocks, which changes from a calcium bicarbonate type in areas of recharge to a calcium sulfate type in local areas of natural discharge (Norris and Fidler 1973).

The quality of the water sampled from the Newburg zone east of western Franklin County, OH, is comparatively poor in comparison to other ground-water sources in the area. Water-quality data are listed for the Newburg zone in central Ohio; as indicated, water from this zone is very hard and commonly contains elevated concentrations of dissolved solids (Table 1).

TABLE 1

Analyses of water from the "Newburg sand" (drillers' term) at Harrisburg, Plain City, and Grove City.

Properties and constituents	Harrisburg (2-16-55)	Plain City (2-15-55)	Grove City (10-23-54)
Specific conductance (microsiemens per centimeter at 25° C)	1,050	1,040	2,460
pH	7.4	7.2	7.0
Color, units	5	5	3
Hydrogen sulfide	.1	.5	3.6
Hardness as $CaCO_3$:			
Calcium and magnesium	532	573	1,570
Noncarbonate	213	226	1,310
Total hardness	745	799	2,880
Calcium	134	143	424
Magnesium	48	52	124
Sodium	35	19	51
Potassium	3.4	3.5	5.8
Bicarbonate	389	420	316
Carbonate	0	0	0
Sulfate	239	235	1,220
Chloride	23	12	84
Fluoride	2.1	1.7	2.3
Silica	15	11	10
Dissolved solids (residue on evaporation at 180° C)	720	724	2,230
Nitrate	.2	.2	.4
Iron	.37	.75	.36
Manganese	.00	.00	.00

All values in parts per million unless noted otherwise.
(From Norris 1956)

In eastern Ohio, the Newburg zone yields a widely distributed brine (Stout et al. 1932). Production and manufacturing of salt from the Newburg brine was common during the 1800s throughout most of eastern Ohio and as far west as Jackson, Licking, and Morrow counties (Stout et al. 1932). There are no references to the Newburg as a source of potable water in eastern Ohio.

POSSIBLE ORIGINS OF THE POROSITY AND PERMEABILITY OF THE NEWBURG ZONE

The relatively high permeability and porosity of the Newburg zone has been attributed to: 1) deposition of sands, later lithified into porous and permeable sandstone along an erosional surface near the top of the Lockport Dolomite in eastern Ohio; 2) geochemical dissolution of dolomitized fossils within Silurian reef complexes, which has created vugs in the rocks in western and northern Ohio; and 3) solution of the Silurian carbonates along faults and fractures in southeastern Ohio, which resulted from tectonic activity associated with the Acadian and Alleghenian orogenies.

Sediment Deposition on an Erosional Surface

The theory of sediment deposition on an erosional surface was first postulated by Stout et al. (1932). They described the Newburg zone as a unit containing thin lenses of sandstone that represent original shoreline deposits of sand left along a surface of disconformity. Stout et al. (1935), Lafferty (1949), and Collins and Smith (1977), among others, discussed the presence of sandstone along this surface, although there is some disagreement over the composition of the sandstone.

The contact between the Lockport Dolomite and the overlying Salina Formation marks the position of the Newburg zone in some localities; but, in general, the position of the Newburg zone is not stratigraphically fixed. The presence of the Newburg zone throughout much of the upper Lockport Dolomite in northeastern Ohio, the lower part of the Salina Formation in southeastern Ohio, and the lower Bass Islands Group in western Ohio (Fig. 2) may indicate a widespread erosional event over the region; however, the sporadic occurrence and variable stratigraphic position of the Newburg zone suggests that the Newburg zone represents several erosional surfaces that do not relate to the same erosional event. Drilling data indicate that the Newburg zone is present within the Lockport Dolomite at some places and stratigraphically above it nearby. This supports the theory of an origin from multiple discontinuous erosional surfaces rather than a single, continuous surface. Because the carbonate units that constitute the "Big Lime" are relatively continuous vertically and may be hydraulically connected in parts of Ohio, the various permeable zones would function as a single unit. Detailed mapping based on drilling logs, drill cuttings, and geophysical logs would be required to improve an understanding of the continuity of the Newburg zone.

Dissolution of Fossils in Reef Complexes

Floto (1955) wrote that the Newburg zone has certain structural and depositional characteristics associated with Niagaran-age reefs. These include relatively sharp closure of the structural contours, variations in the stratigraphic elevation of the Newburg zone caused by differential compaction on the reef complex, and local thickening of the Newburg zone at oil fields and gas fields; however, cuttings examined by Floto from two producing fields in northeastern Ohio offer no evidence of reef origin. Floto attributed this lack of evidence to erosional, biological, and diagenetic processes that erased organic structures and produced a dense, massive carbonate rock unit. Floto based much of his argument for the presence of the Newburg zone on the development of rocks formed from sediments deposited along the postulated position of the ancient shoreline of the Niagaran sea and the documented occurrence of reef complexes in this environment (Fig. 3).

Porosity and permeability within the Newburg zone have been attributed to the composition and fabric of ancient reef complexes at this stratigraphic level. Stromatoporoid structures at the top of the Newburg zone

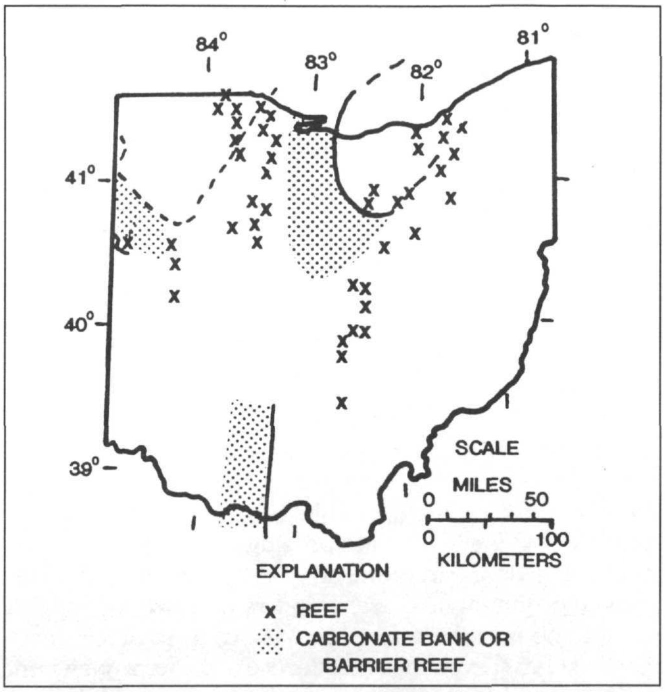
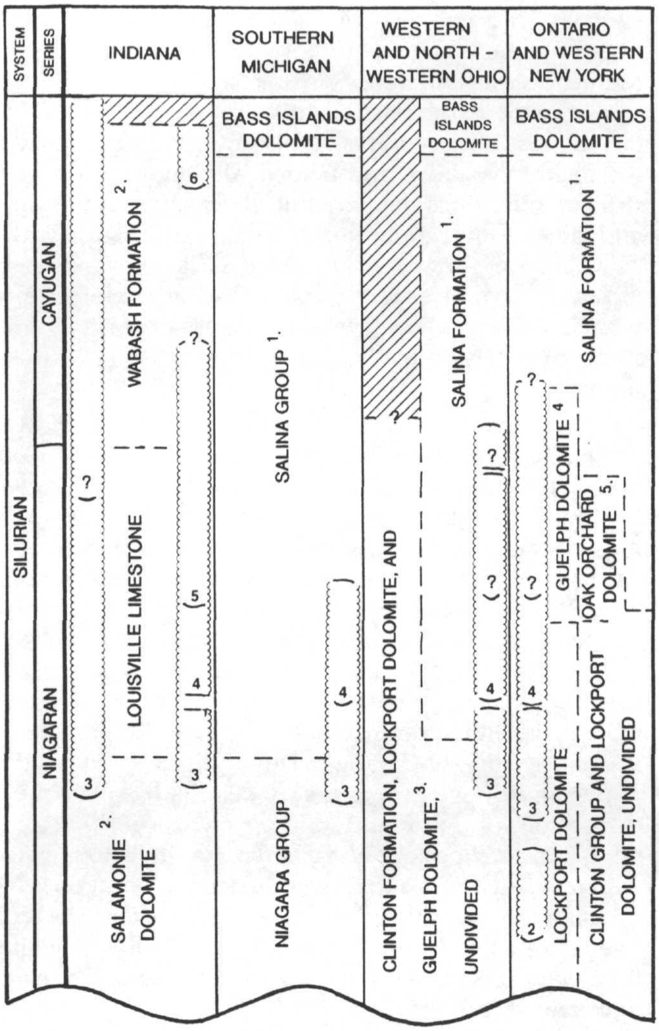


FIGURE 3. Selected reefs and carbonate banks or barrier reefs in Silurian rocks of Ohio. (Modified from Shaver et al. 1978.)

at the Moreland oil pool, Wayne County, OH, are well documented by Multer (1963). According to Multer, physical evidence, such as fossils of reef-forming organisms (brachiopods, gastropods, stromatoporoids, and corals), and structural evidence, such as slumping and sliding being confined to the immediately overlying gray dolomite, indicates the possibility of a reef origin. Multer suggested that the porosity and permeability of the Newburg zone appear to be related to: 1) solution by ground water that dissolved fossils and left a vuggy texture; 2) open fractures; 3) stylolites; and 4) secondary mineralization within the vugs.

The variations in the stratigraphic position of the Newburg zone may be associated with the occurrence of reef complexes. Reef cyclicity—the occurrence of successive reef generations in a certain area (Shaver and Sunderman 1989)—is characteristic of the Silurian sequence in Ohio rocks of the Appalachian Basin as it is for Silurian rocks of the Illinois and Michigan Basins (Fig. 4). Cycles of reef growth can result in differences in the vertical stratigraphic position of the Newburg zone. Likewise, differential compaction of sediments on and around reefs could have resulted in stratigraphic and regional discontinuities in the presence of permeable zones.

Close examination of these data suggests that the hypothesis that the high permeability of the Newburg zone results from the presence of reefs is inconsistent across the state. In northwestern Ohio, where reef structures in the Silurian rocks are well documented in outcrops, quarries, and cores, the Newburg zone is not present. In their ground-water study of northwestern Ohio, Norris and Fidler (1971) found high-yielding bedrock wells in structurally high areas associated with ancient reefs; however, they did not find a specific water-yielding zone correlative to the Newburg zone in central Ohio. They



EXPLANATION

REEF GROWTHS, NUMBERED SEQUENTIALLY (i.e. 1 = OLDEST, 6 = YOUNGEST)

1.- USGS USAGE IN UPPER SILURIAN ONLY
2.- FOLLOWS USAGE OF THE INDIANA GEOLOGICAL SURVEY (SHAVER ET AL. 1978)
3.- FOLLOWS USAGE OF THE OHIO GEOLOGICAL SURVEY (JANSSENS 1977)
4.- FOLLOWS USAGE OF THE GEOLOGICAL SURVEY OF CANADA (BOLTON 1957)
5.- FOLLOWS USAGE OF THE NEW YORK GEOLOGICAL SURVEY (FISHER AND BRETT 1981)

FIGURE 4. Generalized stratigraphic chart for the Great Lakes area showing principal reef rock. (Modified from Shaver et al. 1978.)

suggested that the Newburg zone exists in northwestern Ohio, but specific evidence to support this hypothesis was not found in their study (Norris and Fidler 1973).

Tectonic Influences of the Appalachian Basin

Synclines, arches, and faults are evidence of the tectonic activity in eastern and southeastern Ohio (Figs. 5 and 6), which accompanied the Alleghenian orogeny in the late Carboniferous-Permian time. The same tectonism that produced the valley-and-ridge folding to the east of Ohio produced westward thrusting of less than 1.6 km in the rocks above the E-unit salt of the Salina Formation in east-central Ohio (Janssens et al. 1976). Rodgers (1963) suggested that the Burning Springs anticline of West Virginia and Ohio formed from slippage along the plastic salt layers of the Upper Silurian rocks. The overlying strata

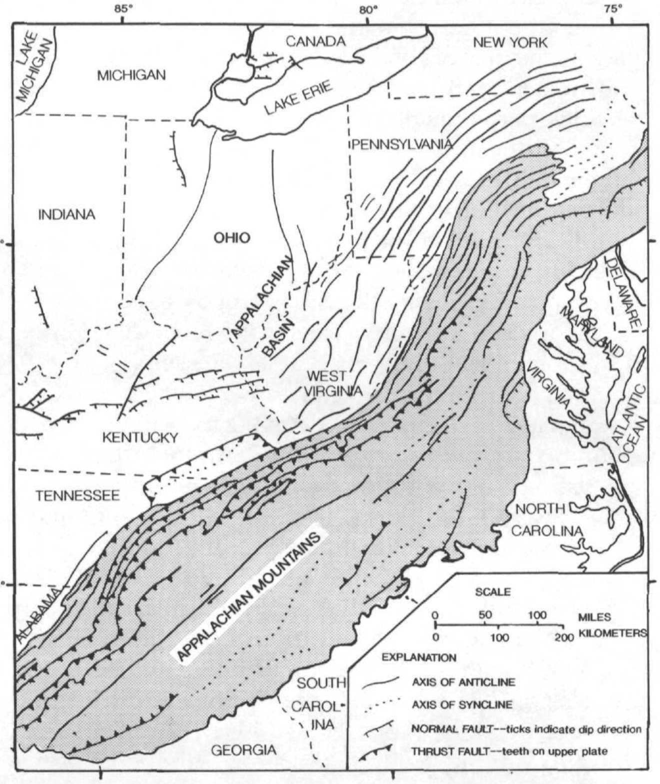


FIGURE 5. Generalized map of selected tectonic features west of the southern and central Appalachians. (Modified from King 1969, Norris 1974, Norris 1975, Collins and Smith 1977.)

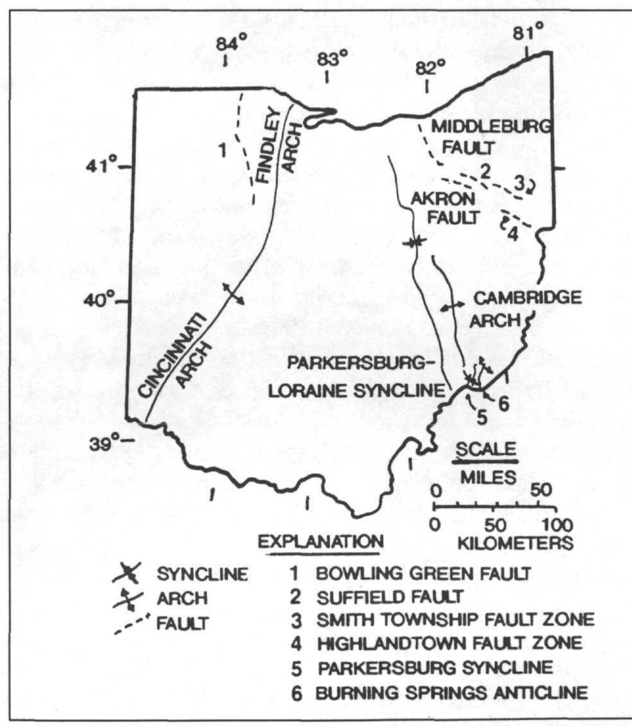


FIGURE 6. Major synclines, arches, and faults in Ohio. (Compiled from Rodgers 1963, Norris 1974, Norris 1975, Collins and Smith 1977, Gray 1982, Gray et al. 1982.)

were thrust to the northwest. Clifford and Collins (1974) attributed the Cambridge arch to movement along a salt glide plane in rocks of the Salina Formation. Calvert (1983) constructed structural sections from gamma-ray logs of sections perpendicular to the Burning Springs anticline south of the Ohio River. He found a strike-slip fault penetrating into the Lockport Dolomite and major thrusting and deformation in the overlying Salina Formation and Bass Islands Group associated with movement along a decollement surface in the Silurian salt. Again, movement was in response to compression during the Allegheny orogeny.

The interest in Silurian salts is the result of oil and gas developments in these rock units. Janssens et al. (1976) determined from cores that fracture porosity is responsible for reservoirs in the upper salt unit of the Salina Formation (F-unit) and that primary porosity is absent in the host rock consisting of dolomite mudstone interbedded with anhydrite. Clifford and Collins (1974) suggested an association between the Cambridge arch and the production of hydrocarbons from units in the Salina Formation.

The Newburg zone, stratigraphically near the Lockport Dolomite and the Salina Formation, could therefore be the result of fracture-induced porosity along a slip plane in eastern Ohio. The presence of brine in the Newburg zone in eastern Ohio (Stout et al. 1932) and evidence of thrusting in the Salina Formation salt beds provides support for a tectonic origin of the zone. If the amount of lateral displacement is minor and the physical evidence of a thrust plane (melange, slickensides) are erased by dissolution of the carbonate bedrock by ground water, it is probable that structural changes along a thrust plane may go unrecognized in core samples.

Multiple Processes

As evident from the hypotheses presented above, there are valid arguments for and against each theory for origin of the Newburg zone. Lithologic and structural characteristics documented at certain localities do not appear to apply to the entire study area. Keeping in mind that the Newburg zone is largely a term used by drillers for a permeable zone commonly found within the "Big Lime," geologic factors that produced a Newburg zone in one area may be different from those in another area; however, these multiple processes could result in stratigraphically common permeable zones at different localities.

It is suggested, therefore, that the Newburg zone in Ohio is the result of multiple processes that produced a generally continuous, permeable stratigraphic zone. In southeastern Ohio, the Newburg zone may be the result of porosity caused by fracturing in lower beds of the Salina Formation. It is restricted to this region, owing to the localized tectonism associated with the development of the Cambridge arch, Burning Springs anticline, and other structural features (Fig. 6).

In West Virginia, drillers refer to the Williamsport Sandstone as the Newburg zone, a designation that probably influences terminology used in Ohio drilling reports. Occurrences of ancient reef structures at some Newburg zone localities in northeastern Ohio (Floto 1955, Multer 1963) and sandstone deposits at other sites (Stout et al. 1935, Lafferty 1949) indicate reef growth, erosional surfaces, or a combination of the two processes as an origin for the Newburg zone. Norris and Fidler (1973) found no strong differences in lithology between rocks of a cavity zone in the Bass Islands Group of western Ohio (which possibly represents the Newburg zone) and that of the rock units above and below. Although ancient reef structures are documented in northwestern Ohio, Norris and Fidler were careful not to suggest an origin for the Newburg zone; however, they stated that evidence strongly indicates a correlation of the highly permeable zone of western Ohio with the Newburg zone of eastern Ohio, and that the zone is probably continuous.

SUMMARY

The Newburg zone in Ohio is a zone of high porosity and permeability that is as much as 9 m thick and is noted for contained water, oil, and gas reserves. Lithologically, it is generally considered to be a granular or vuggy dolomite near the contact of the Lockport Dolomite and Salina Formation of Silurian age, the Newburg zone is neither well defined nor stratigraphically confined.

It is possible that the only similarity between the Newburg zone of northeastern, southeastern, and western Ohio may be the presence of a permeable zone within a specific stratigraphic range. Descriptions cited in this paper indicate erosional surfaces with subsequent deposition of sand and development of sandstone, dissolution of limestone and invertebrate shells associated with reef structures, and tectonic deformation as possible origins for the Newburg zone of Ohio. Therefore, the term "Newburg zone" is only regionally applicable. Whether the Newburg zone is a single hydrogeologic unit remains uncertain at this time.

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